TOPIC 3 – PERIODICITY
3.3 – CHEMICAL PROPERTIES

IB Chemistry

T03D03

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3.1 – Chemical Properties – 3 hrs

- 3.3.1 Discuss the similarities and differences in the chemical properties of elements in the same group. (3)
- 3.3.2 Discuss the changes in nature, from ionic to covalent and from basic to acidic, of the oxides across period 3. (3)

Chemical Down a Group

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3.3.1 Discuss the similarities and differences in the chemical properties of elements in the same group. (3)

- As discussed, chemical properties are repeated each group in the periodic table, that's how Mendeleev organized it
- We will look at the first three elements in the group, then at the halogens

Chemical Properties of Alkali Metals

- Very reactive metals, atomic and physical properties:

Element	Lithium	Sodium	Potassium
Electron Arrangement	2,1	2,8,1	2,8,8,1
Electron Configuration	$1s^2 2s^1$	$1s^2 2s^2 2p^6 3s^1$	$1s^2 2s^2 2p^6 3s^2 3p^6 4s^1$
Chemical Symbol	Li	Na	K
First I.E. (kJ mol^{-1})	519	494	418
Atomic Radius (nm)	0.152	0.186	0.231
Melting Point (K)	454	371	337
Boiling Point (K)	1600	1156	1047
Density (g cm^{-3})	0.53	0.97	0.86
Standard Electrode Potential (E^o)	-3.03	-2.71	-2.92

- The Standard Electrode potential is a measure of reducing agent strength, more negative values have a greater tendency to lose an electron in aqueous solution.

3.3

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Chemical Properties of Sodium (Na)

- Soft silvery-white metal (as a solid)
- Great conductor of heat and electricity
- Corrodes in air to form Na_2O
  - $2Na(s) + O_2(g) \rightarrow Na_2O(s)$
- When placed in water, floats and reacts immediately
  - $2Na(s) + 2H_2O(l) \rightarrow 2NaOH(aq) + H_2(g)$
  - Exothermic reaction, burns bright yellow
- Sodium hydroxide (base) is completely ionized in H_2O
  - $2Na(s) + 2H_2O(l) \rightarrow 2Na^+(aq) + 2OH^-(aq) + H_2(g)$
  - Sodium acts as a reducing agent here (oxidized)
- When burned in halogen gas, the salt is formed:
  - $2Na(s) + Cl_2(g) \rightarrow 2NaCl(s)$

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Chemical Properties of Potassium

- Potassium is a soft silvery metal
  - Good conductor like sodium
  - Reactions are identical to sodium, but less vigorous due to lower 1st I.E.
  - Unlike Na, the reaction of potassium with water releases enough heat to ignite the produced hydrogen
    - Burns with a pale purple flame

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Chemical Properties of Lithium

- Lithium is a hard silver metal
  - Reactions identical to sodium but slower due to a higher 1st I.E.
  - Reaction in water less impressive and less exothermic

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Chemical Properties of Halogens

- Very reactive non-metals, atomic and physical props:

Element	Chlorine	Bromine	Iodine
Chemical Formula	Cl_2	Br_2	I_2
Structure	Cl-Cl	Br-Br	I-I
Electron Arrangement	2.8.7	2.8.18.7	2.8.18.18.7
Noble Gas Notation	$3s^2 3p^5$	$4s^2 4p^5$	$5s^2 5p^5$
State at S.T.P.	Gas	Liquid	Solid
Color	Green	Red-brown	Black
Melting Point (K)	172	266	387 (458 Sublime)
Boiling Point (K)	239	332	----
Standard Electrode Potential (E^o)	1.36	1.09	0.54

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General Reactivity of Halogens

- All have valence shells of 7 electrons
- Noble Gas configuration is obtained by gaining $1e^-$
  - Forms a halide ion or covalent bond
- All exist as diatomic molecules (BrINClHOF)
  - Br_2, I_2, Cl_2, H_2, O_2, F_2
- All colored and become progressively darker down the group
- Volatility decreases down the group due to increased Van der Waals forces

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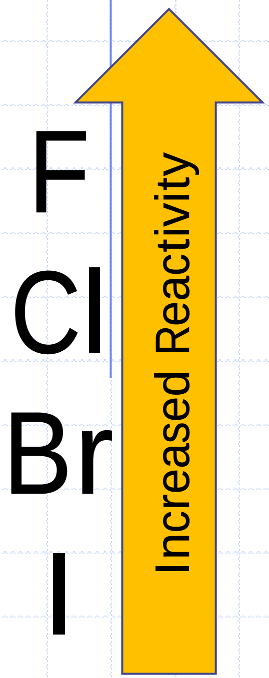
Halogen Reactions: Displacement



- Halogens want to gain electrons (becoming halides, ionic) in solution. Most reactive wins
  - $Cl_2(aq) + 2F^-(aq) \rightarrow$ N.V.R. (no visible reaction)
    - Fluorine is more reactive, no reaction
  - $Cl_2(aq) + 2Br^-(aq) \rightarrow Br_2(aq) + 2Cl^-(aq)$
  - $Cl_2(aq) + 2I^-(aq) \rightarrow I_2(aq) + 2Cl^-(aq)$
  - $Cl_2(aq) + 2At^-(aq) \rightarrow At_2(aq) + 2Cl^-(aq)$
- These are redox (reduction/oxidation) reactions that will be covered in Topic 09.

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Halide Ion Reactions

- Halides refer to halogen ions: F^-, Cl^-, Br^-, I^-, At^-
  - Present in metal salts ($NaCl$, $MgBr_2$, etc)
- Halide ions are colorless which makes them easy to distinguish from their diatomic species
- The colorless halide ions can be distinguished from one another by the addition of silver nitrate ($AgNO_3$)
  - $NaF(aq) + AgNO_3(aq) \rightarrow NaNO_3(aq) + AgF(aq)$ CLEAR
  - $NaCl(aq) + AgNO_3(aq) \rightarrow NaNO_3(aq) + \mathbf{AgCl(s)}$ WHITE
  - $NaBr(aq) + AgNO_3(aq) \rightarrow NaNO_3(aq) + \mathbf{AgBr(s)}$ WH/YEL
  - $NaI(aq) + AgNO_3(aq) \rightarrow NaNO_3(aq) + \mathbf{AgI(s)}$ YELLOW

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Chemical Across a Period

3.3.2 Discuss the changes in nature, from ionic to covalent and from basic to acidic, of the oxides across period 3. (3)

- Metallic oxides tend to be **ionic and basic**
- Alkali metals, alkaline earths; **Alkaline = basic**
  - $Na_2O(s) + H_2O(l) \rightarrow 2NaOH(aq)$
  - $MgO(s) + H_2O(l) \rightarrow Mg(OH)_2(aq)$
- Aluminum is amphoteric, reacts with both acids and bases:
  - $Al_2O_3(s) + 6HCl(aq) \rightarrow 2AlCl_3(aq) + 3H_2O(l)$
  - $Al_2O_3(s) + 2NaOH(aq) + 3H_2O(l) \rightarrow 2NaAl(OH)_4(aq)$
- Non-metallic oxides are **covalent and acidic**
  - $P_4O_{10}(s) + 6H_2O(l) \rightarrow 4H_3PO_4(aq)$
  - $SO_3(g) + H_2O(l) \rightarrow H_2SO_4(aq)$
  - $Cl_2O(g) + H_2O(l) \rightarrow 2HClO(aq)$

Natural Rain: Carbonic Acid

- Natural rain water is **acidic**, with a pH around **5.6**
- The acidity of rain is a result of **CO_2** naturally present in the atmosphere
- When CO_2 is dissolved in water it's referred to as **carbonic acid (H_2CO_3)** but only a very small amount actually exists as a solution
  - $H_2O + CO_2 \rightarrow H_2CO_3$
- Carbonic acid molecules immediately dissociate in water to form **hydrogencarbonate ions, HCO_3^-**, and **hydronium ions, H_3O^+**
  - $H_2CO_3 + H_2O \rightleftharpoons HCO_3^- + H_3O^+$

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Acid Rain: Formation

- The most important sources of acid rain are the sulfur oxides produced in power stations
- When sulfur oxides dissolve and react in rain water, solutions of sulfuric acids are formed (as discussed in E.1)
  - $SO_2 + H_2O \rightarrow H_2SO_3$
  - $SO_3 + H_2O \rightarrow H_2SO_4$
- During combustion of fuels in car engines, oxides of nitrogen are produced as NO, NO_2, N_2O, etc
  - These rapidly react in air to form HNO_3 (nitric acid) which is also a contributor